RASTER NAUTICAL CHART PROJECT REPORT:

Survey of NOAA Raster Chart Users

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BIOGRAPHY:

Captain Stephen F. Ford is a 1970 graduate of the U.S. Merchant Marine Academy with a 1978 MBA from the University of Houston. He is a Master Mariner of fifteen years seagoing experience; Past Vice President of a U. S. flag shipping company of nine vessels; and Head of Marine Transportation Department of Texas A&M University at Galveston from 1988 to 1996. Captain Ford served as the P.O.R.T.S. Manager of the Houston/Galveston system from 1995 to 1998. He has had eight years service on the USCG Navigation Safety Advisory Committee (NAVSAC) and is a fourteen year member of the Houston/Galveston Navigation Safety Advisory Council (HOGANSAC). An additional five years service on the Houston Pilot Review Board amply qualifies him for his technical, academic, expert and consultant roles in the U. S. maritime industry.

Captain Ford has provided key leadership roles to the U. S. Coast Guard and the National Oceanic and Atmospheric Administration. As the first Chair of NAVSAC's Navigation Equipment Committee, he significantly influenced the development of Electronic Chart Display and Information Systems (ECDIS). As one of ten key maritime industry personnel, he participated in a 1993 NOAA initiative concerning "Modernizing Navigation Services" to guide senior government leaders in their preparation for the 21st Century.

In the mid-1970's Captain Ford developed the first electronic chart that was the prototype to modern electronic navigation charts (ENC) and ECDIS devices. For the 1990's, he has proposed the development of "SMART CHARTS" for the second generation of ECDIS units. This concept includes real-time sensor inputs to ENC's in to order provide mariners with a "Management Information System" onboard their vessel. He has significant experience with Geographic Information Systems (GIS) and pursues research to meld this science with nautical charting. In addition to his professional activities, he has produced several dozen publications on a variety of maritime subjects.

ABSTRACT:

In accord with the terms of NOAA requisition # NC-NJ0000-8-00009, a Raster Chart Display System (RCDS) User Survey and Field Test was conducted during May of 1998. The principal operations area of the study was the Texas Gulf Coast of the United States. The Survey participants were RCDS users from Royal Caribbean Lines and Hollywood Marine, Inc.

The purpose of the 102 question RCDS User Survey was to gather experience with respect to Paper Charts from "on the water" users of NOAA 's new raster nautical chart product in the areas of :

- Voyage Planning (33 Questions)
- Voyage Monitoring (53 Questions)
- Voyage Recording (6 Questions)
- Other (10 Questions)
- General Comments
- Total = 102 Questions

A field test of the NOAA raster charts was conducted on an IBM, P133 platform with Pinpoint Inc. software. The field test was to assess the author's personal and professional

satisfaction with surveying NOAA raster charts in an operating environment. The area of the field test was the Houston Ship Channel and the U.S. Gulf Intra-coastal Waterway.

Completion of the User Survey form (Appendix 1) was accompanied by author interviews of respondents in thirteen of the 33 submitted responses. Appendix 1 contains the project's mean response evaluations on a per question basis and "n-number" of responses. Respondents general, professional comments are summarized in Appendix 2. Appendix 3 contains copies of the individual surveys submitted by the respondents.

The study documents:

- respondents very positive responses in support of RCDS as compared to a paper chart.
- author's positive field-check experience during a 200 mile Intra-coastal waterway (ICW) journey.
- RCDS user's candid, positive comments.
- RCDS adds to the safety and efficiency of navigation.

The respondents were overwhelmingly positive with respect to the improvement of RCDS over the paper chart. On the survey scale of 1.0 (much worse than paper chart) to 5.0 (superior to Paper chart), the survey results and confidence intervals for each survey section were:

	n Responses	Mean Response	95% Lower Conf. Int	95% Upper Conf. Int	PerCent "5" Answers
	====	=====	======	======	======
1. RCDS as a Voyage Planning Tool (Questions # 1.1 to 1.33)	989	4.50	4.45	4.55	69%
2. RCDS for Voyage Monitoring (Questions # 2.1 to 2.53)	1362	4.63	4.59	4.67	76%
3. RCDS for Voyage Recording (Questions # 3.1 to 3.6)	160	4.63	4.51	4.76	77%
4. OTHER (Questions # 4.1 to 4. 10)	268	4.71	4.63	4.80	80%

The paper concludes with a an assessment of strong, positive support for NOAA's raster charts and RCDS as an improvement in navigation safety and efficiency. The most significant result of the survey was assessment of 100 % of the respondents support for the following statement:

> ***"RCDS with adequate back-up arrangements used together with an appropriate folio of up-to-date paper charts…may be accepted as complying with the chart carriage requirement of SOLAS."***

BACKGROUND

The Safety Of Life At Sea (SOLAS) Convention of 1977 provides chart carriage requirements to governments and mariners. In the late 1980's electronic nautical charts (ENC) evolved into Electronic Chart Display and Information Systems (ECDIS). The International Maritime Organization (IMO) provides the machinery for cooperation among governments relating to technical matters affecting international shipping. The IMO ECDIS performance standard delineated vector charts as one of the requisites for an "ECDIS" approval. After approval, ECDIS devices could be carried in lieu of paper charts. Because vector chart construction is a very time consuming process, a full suite of vector charts will not be available for many years. Chart production by national government Hydrographic Offices is necessary for sustainable development of the electronic chart medium. Lack of IHO charts and associated legal concerns thwarted the initial electronic chart initiative in the mid-1970's and delayed the development of the current state-of-the-art ENCs ten years.

In the 1990's, after six years of development, NOAA and other International Hydrographic Offices (U.K. and Australia) released raster nautical charts (RNC) for use by their constituencies in Raster Chart Display Systems (RCDS). An RNC is an accurate digital facsimile of an official paper chart. The primary function of the RCDS is to contribute to safe navigation. An RCDS has most, but not full, ECDIS functionality and mariners must be fully cognizant of datum and projection differences between the charts. Australia, United Kingdom, the United States and many other nations support the use of raster charts developed by government Hydrographic Offices for those areas where ENCs have yet to be produced. The suitability and acceptance of raster charts for RCDS as satisfying the chart carriage requirement of the SOLAS Convention is under international evaluation at the present time.

As part of the evaluation of raster charts, NOAA's Office of Coast Survey contracted with Texas A&M University at Galveston for the services of the author to conduct a raster chart User Survey and interviews with respect to a comparison of RCDS to the paper chart navigation methods. In addition, a field check of NOAA's raster chart product was requested. Two deep-sea users responded and thirty-one "brown water" sailors participated in this survey. This report documents the results of the project.

The User Survey and Field Test form (Appendix 1) was developed with the specific intent of not only statistical analysis of respondent's numerical answers, but also capturing the avante garde remarks of the operators.

USER SURVEY

The Raster Chart Display System Survey form (Appendix 1) was divided into six parts:

- **User Profile -** a series of short answer questions to document operator experience and background and navigation environment as well as hardware/software data.

- **Part 1 RCDS as a Voyage Planning Tool -** a series of 33 questions addressing navigation functions of a raster chart compared to comparable functions on a paper chart.
- **Part 2 RCDS for Voyage Monitoring** - a series of 53 questions addressing navigation functions using a raster chart as compared to comparable functions on a paper chart.
- **Part 3 RCDS for Voyage Recording** - six questions comparing RCDS to paper chart performance, where appropriate.
- **Part 4 Other Questions** - ten miscellaneous questions comparing RCDS to paper chart performance, where appropriate.
- **Part 5 Other Comments** - Operator comments relevant to the use of RCDS as the primary means of navigation.

The author during the project interviewed thirteen of the thirty-three respondents. The operator's interview comments are contained in Appendix 2. Respondents were randomly selected by chance from the Hollywood Marine Fleet as their vessels docked at the Houston Ship Channel facility. Respondents were only required to complete questions appropriate to their experience and professional stance on the subject area. Every question was not answered by every respondent. Hence, the distribution of the aggregated group responses are the best indicator of the degree of user satisfaction with the Planning, Monitoring, Recording and Other categories. A numerical evaluation was utilized on a scale of 1.0 (much worse than a paper chart) to 5.0 (superior to a paper chart). Statistically, the survey responses were bounded by an upper limit of five on the "1 to 5 answer scale". Hence, where appropriate, Cumulative Probability statistics are utilized to interpret the survey results.

EVALUATION SCALE (use for all questions)

DESCRIPTORS & SCORE					
does not apply	**much worse than paper chart**	**somewhat worse**	**comparable to paper chart**	**somewhat better**	**superior to paper chart**
0	**1**	**2**	**3**	**4**	**5**
cannot comment	**significant problem**	**minor problem**	**no problem**	**minor advantage**	**significant advantage**
0	**1**	**2**	**3**	**4**	**5**
did not observe	**hard to use**	**moderately difficult use**	**adequate ease of use**	**moderately easy to use**	**easy to use**
0	**1**	**2**	**3**	**4**	**5**
did not use	**inadequate**	**marginal**	**acceptable**	**good**	**excellent**
0	**1**	**2**	**3**	**4**	**5**

EVALUATION SCALE (use for all questions)

USER SURVEY PROFILE

The mean profile of the typical Raster Chart Survey respondent was a mariner of:

- one year of RCDS experience
- 21 years of helm or navigation experience and/or 15 years as Captain or 7 years as Pilot
- operating time distribution - 16 % open water; 28 % coastal; 22 % harbor; 46 % channels; 11 % docking
- visibility distribution - 38 % excellent; 25% fair; 21% poor; 19 % no visibility
- traffic density distribution - 34% heavy; 36% medium; 39% light traffic
- sea conditions - 38% quiet; 27% light; 23% moderate; 21% heavy seas
- 298 days RCDS operations in the past year

Two of the Survey respondents were blue water passenger ship operators from Royal Caribbean Cruise Lines, Inc. The remainder of the respondents were towboat operators from the owned and chartered fleet of Hollywood Marine Inc. Except where appropriate, the difference in responses between "blue water" and "brown water" sailors was not of significance.

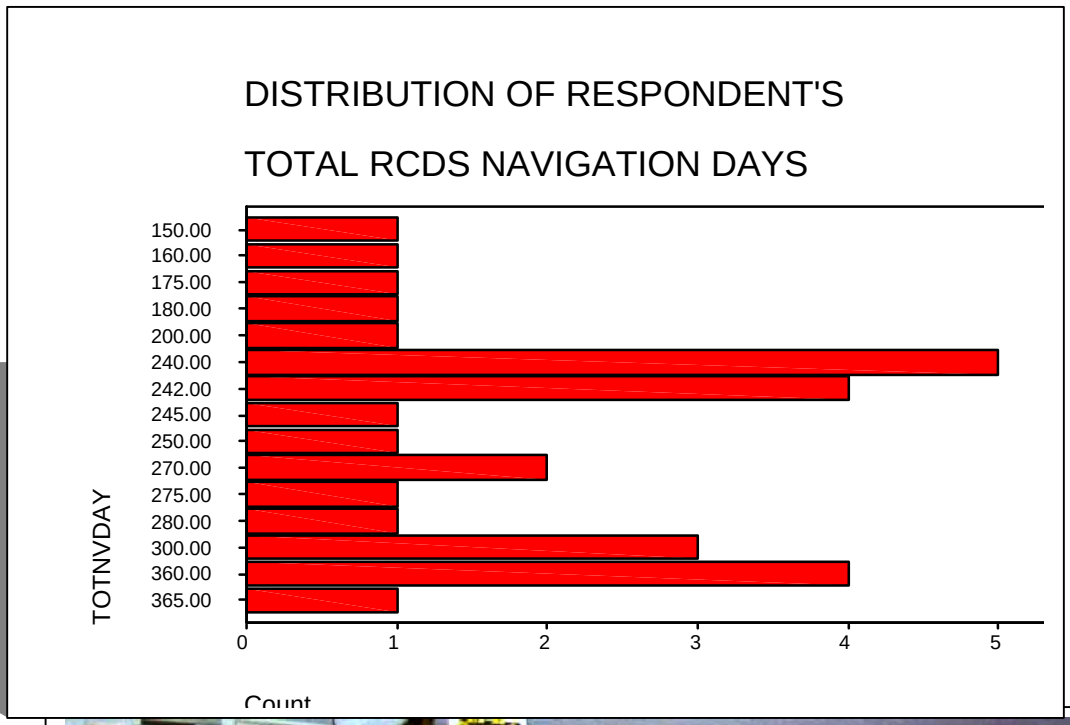
Hollywood Marine Inc. installed 105 RCDS units in their owned and charted fleet of towboats in 1997. Their hardware platform of choice was an IBM P133 PC-computer with a 17-inch monitor of a 640 x 800 resolution. Their choice of navigation software for the display of the raster "softcharts" was the Pinpoint "DVS-1000". All the towboat RCDS integrated the Differential Global Positioning System (DGPS) into the navigation package as the positioning device. One respondent of a chartered vessel identified Loran C as an additional positioning device. All vessels had radar in their wheelhouse, but radars were not integrated into the RCDS navigation display and comments were received as to the desirability of this latter feature. Raster Charts prepared under the authority of NOAA, the United States national hydrographic office, were used in the respondents' RCDS.

RCDS USER SURVEY ANALYSIS

The question by question results of the RCDS survey form are contained in Appendix 1. The Appendix 1 survey results for each question are stated in terms of Mean rating responses and Standard Error of the Mean. The Mean is the measure of the central tendency of the distribution of answers to the survey questions. The Standard Error of Mean is a measure of how much the value of the mean may vary from sample to sample taken from the same distribution. It can be used to roughly compare the observed mean to a hypothesized value. (One can conclude that two values are different if the ratio of the difference to the standard error is less than –2 or greater than +2). The large percentages of ratings of "4" and "5" observed across the survey questionnaires indicate a strong unanimity amongst the respondents.

As an "Approval Rating", the sum of "4" and "5" answer percentages is utilized to capture the degree of positive satisfaction with raster chart/RCDS performance. In a similar fashion, the sum of "1" and "2" answer percentage is deemed an indicator of operator dis-satisfaction with raster charts/RCDS. On average, 76% of all survey responses were a "5" rating or "superior to a paper chart".

Figure 1 DISTRIBUTION OF RCDS NAVIGATION EXPERIENCE (DAYS)



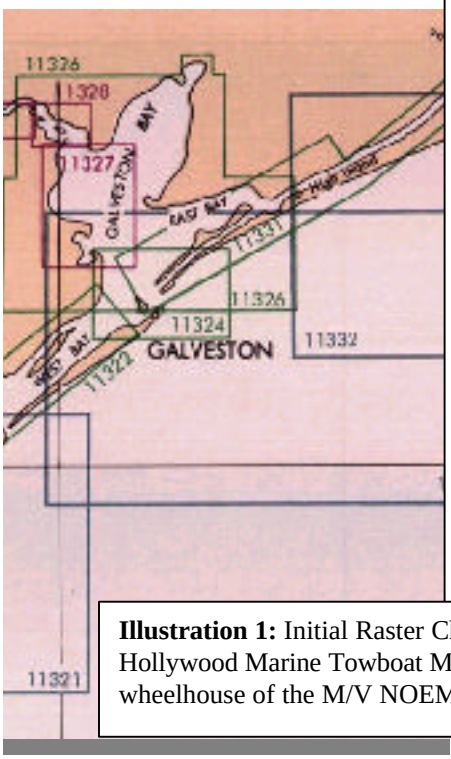


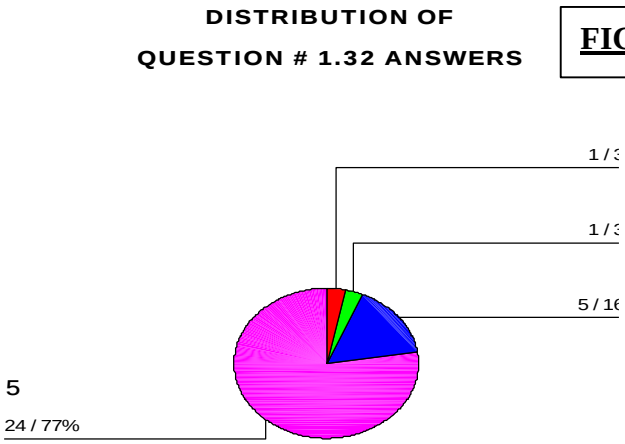
Illustration 1: Initial Raster Chart Field Test was conducted in the upper reaches of the Houston Ship Channel onboard the Hollywood Marine Towboat M/V NOEMA.. Pictured in this narrow 250 ft. wide waterway is the Pinpoint Raster Chart unit in the wheelhouse of the M/V NOEMA while transiting on NOAA Chart No. 11328 and NOAA Chart No. 11327 (Galveston Bay).

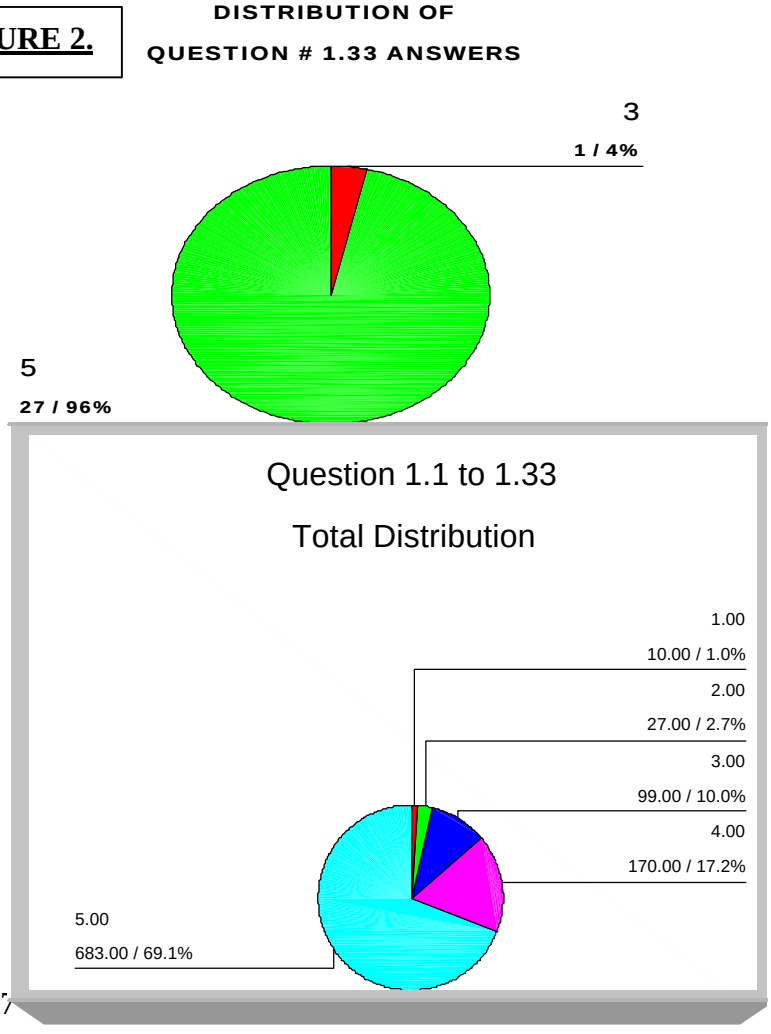
Survey Part 1. RCDS AS A VOYAGE PLANNING TOOL

Part 1 of the survey form requested the operator to evaluate navigation functions with a raster chart compared to doing the comparable function on a paper chart for questions numbered 1.1 to 1.27. An evaluation scale of 1.0 (much worse than a paper chart) to 5.0 (superior to paper chart) with 3.0 being comparable to a paper chart was utilized. The means and standard error of the individual question responses of Part 1 are found in Appendix 1. With only three exceptions (involving chart notes), the mean of each response in this section significantly exceeded the 4.0 evaluation point of "somewhat better than paper chart". Responses to Question # 1.14 indicated that the operators desire an easier methodology of entering , annotating and displaying chart notes and operator-entered marks. However, they still rank the RCDS methodology better than the paper chart. Responses to Question # 1.18 indicate the RCDS is considered only a bit better than the paper chart for preparing a voyage plan; get home chartlet; GPS waypoints.

For questions # 1.28 to 1.33, the operator scored RCDS legibility, planning, impact and limitations without comparison to a paper chart. With the exception of chart notes (#1.30) the mean of each response in this section exceeded the 4.0 evaluation point at a maximum standard error of 0.22. Overall, the 989 responses to Part 1 questions had a mean answer of 4.5 with a 95% confidence interval between 4.45 and 4.55. Figure 2 conveys the 93% positive operator response (4 + 5) to summary Question 1.32 regarding "planning using a raster chart system" and a 96% "Superior To a Paper Chart" response level regarding summary Question 1.33's "fundamental limitations to planning using raster charts". The 86% approval rating (4 + 5) aggregate distribution of all answers to Questions # 1.1 to 1.33 is portrayed in Figure 3. "In toto", these responses indicate an overwhelming operator approval of RCDS as a Voyage Planning Tool with an interpretation of a preference for increased facility in entering operator remarks.

FIGURE 2.





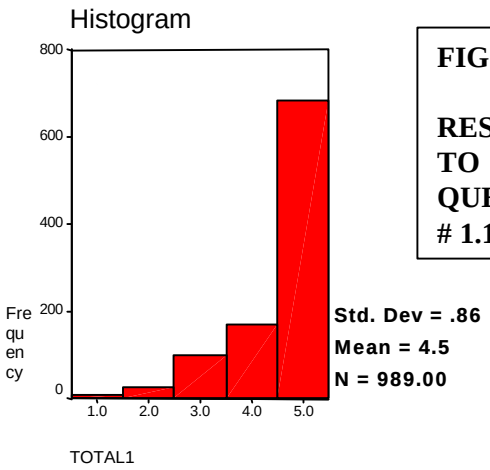
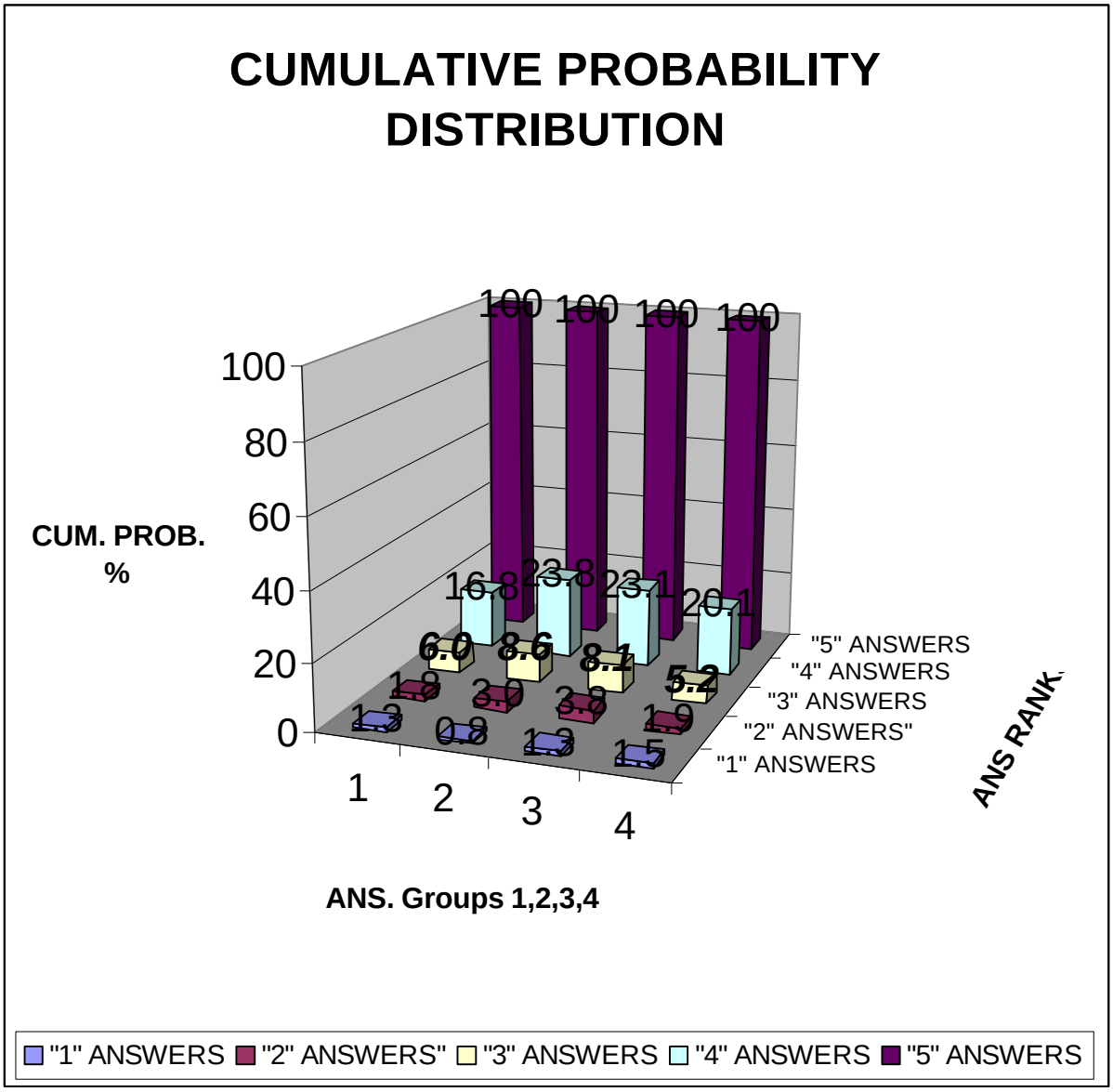


FIG. 3

RESPONSES TO QUESTIONS # 1.1 to 1.33

In light of the observed skewness of the data populations, a Cumulative Probability (Beta) Distribution was calculated on the aggregate answers groups for the four main parts of the survey (Questions 1.1 – 1.33; 2.1 – 2.53; 3.1 – 3.6; 4.1 – 4.10) with respect to their individual cumulative distribution of answer ratings 1, 2, 3, 4, 5 (x-axis). The results of this assessment of the group data are illustrated below.



	1TOTAL (1.1-1.33)	2TOTAL (2.1-2.53)	3TOTAL (3.1-3.6)	4TOTAL (4.1-4.10)
"1" ANS.	1.3	0.8	1.3	1.5
"2" ANS.	1.8	3.0	3.8	1.9
"3" ANS.	6.0	8.6	8.1	5.2
"4" ANS.	16.8	23.8	23.1	20.1
"5" ANS.	100	100	100	100

CUMULATIVE PROBABILITY TABLE

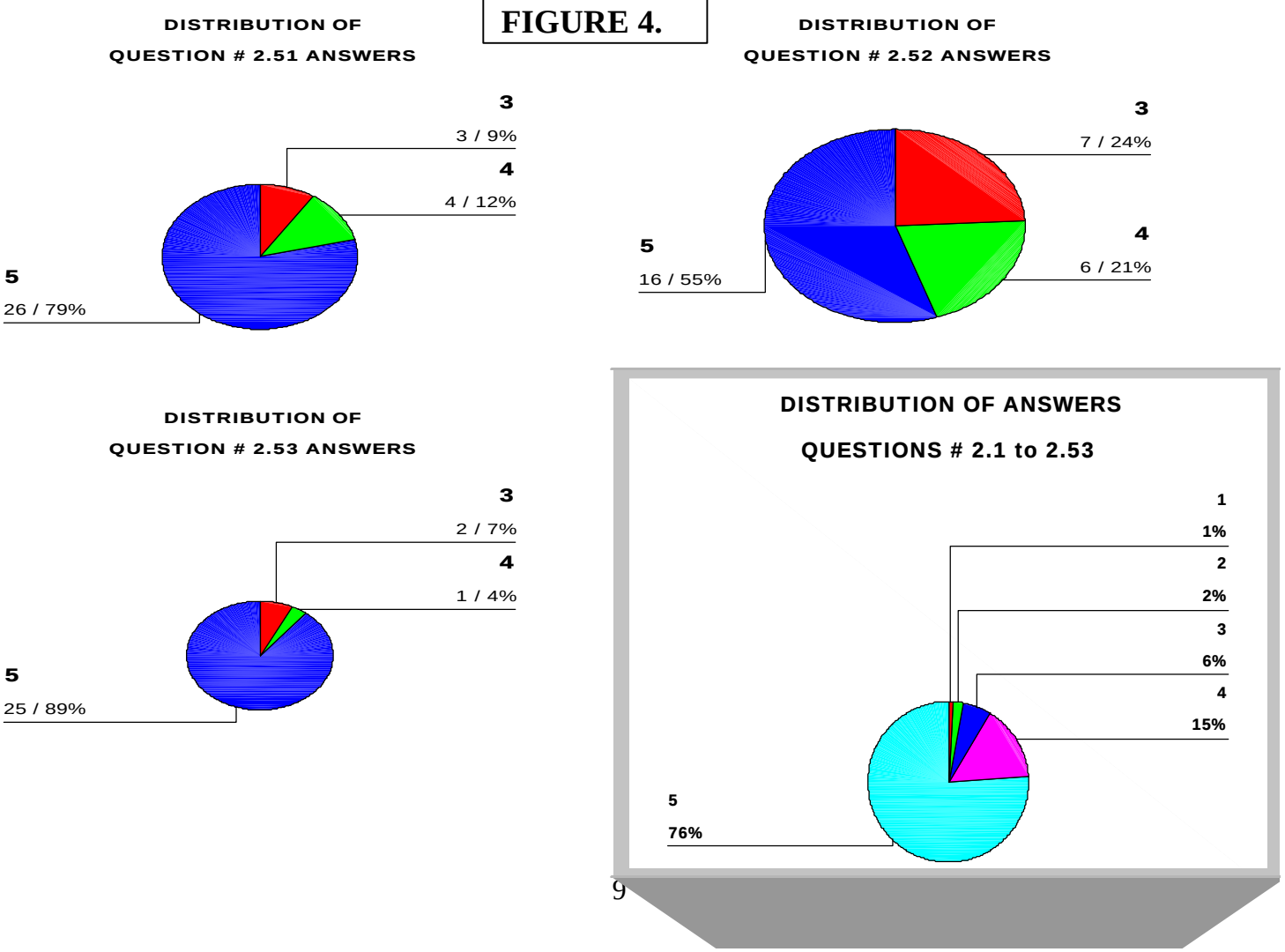
Survey Part 2. RCDS FOR VOYAGE MONITORING

Part 2 of the Survey form requested the operator, where appropriate, to evaluate the execution of navigation functions using a raster chart as compared to doing the comparable functions on a paper chart for Questions # 2.1 to 2.53. The evaluation scale of 1.0 (much worse than a paper chart) to 5.0 (superior to paper chart) with 3.0 being comparable to a paper chart was utilized. The Mean and Standard Error of the individual question responses are found in Appendix 1. The mean of each response in this section exceeded the 4.0 evaluation point of "somewhat better than paper chart".

Questions 2.3, 2.5, 2.7, 2.16 and 2.17 were the only responses with mean scores below the 4.0 rating. In general, like Part 1 responses, these questions reflect a desire for easier manipulation of operator-entered data and chart notes. Question 2.7 reflects operator skepticism with any dead reckoning system because errors inherent in dead reckoning compound too quickly for any degree of reliability.

As evidenced in Figure 4, summary Question 2.51 brought forth a 91% approval rating (4 + 5) evaluating " the impact on safety of navigation when using an RCDS as opposed to a paper chart". Fog, heavy traffic and other navigational limitations came forth in the 76% approval rating (4 + 5) of summary Question 2.52, which sought out "circumstances where you would not use RCDS for voyage monitoring". A 93% approval rating was the response to summary Question 2.53 inquiry regarding "any fundamental limitations to voyage monitoring with raster charts". Overall, the 1,362 responses to Part 2 questions had a mean answer of 4.63. The aggregate distribution of all answers to Questions 2.1 to 2.53 is portrayed in Figure 4. "En globo", the overall 91% approval responses for all Questions 2.1 through 2.53 indicate an overwhelming operator approval of RCDS as a tool for Voyage Monitoring.

FIGURE 4.

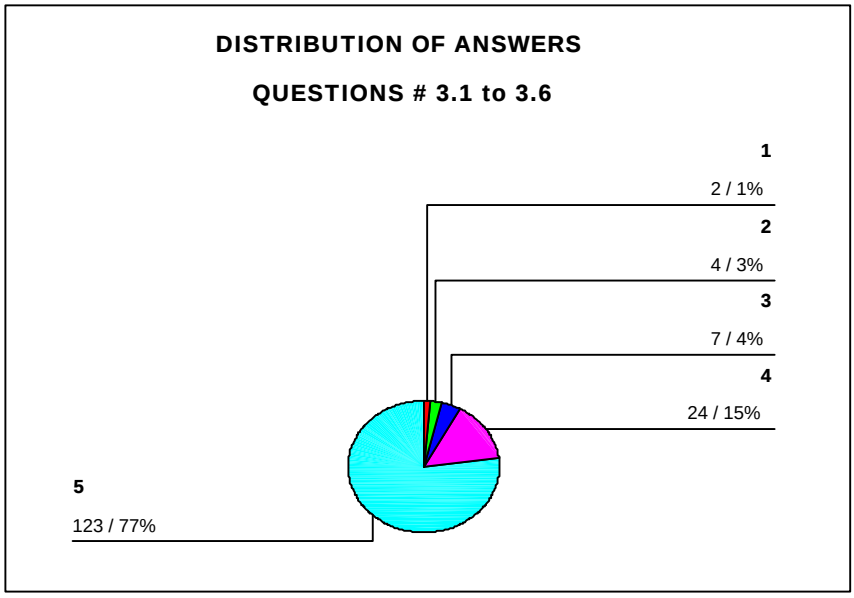


Survey Part 3. RCDS FOR VOYAGE RECORDING

Part 3 of the Survey form requested the operator, where appropriate, to evaluate the RCDS for Voyage Recording functions using a raster chart for voyage monitoring as compared to doing the comparable functions on a paper chart for questions numbered 3.1 to 3.6. The evaluation scale of 1.0 (much worse than a paper chart) to 5.0 (superior to paper chart) with 3.0 being comparable to a paper chart was utilized. The mean of the individual question responses are found in Appendix 1. The mean of each response in this section exceeded the 4.0 evaluation point of "somewhat better than paper chart".

Overall, the 160 responses to Part 3 questions had a mean answer of 4.63. The aggregate distribution of all answers to Questions # 3.1 to 3.6 is portrayed in Figure 5. These 92% approval ratings (4 + 5) of the total responses indicate an overwhelming operator approval of RCDS as a tool for Voyage Recording.

FIGURE 5: VOYAGE RECORDING RESPONSES



Survey Part 4. OTHER QUESTIONS (QUESTIONS 4.1 To 4.10)

Part 4 of the Survey form requested the operator, where appropriate, to evaluate the RCDS for a variety of functions using a raster chart to execute the comparable functions on a paper chart for questions numbered 4.1 to 4.10. The evaluation scale of 1.0 (much worse than a paper chart) to 5.0 (superior to paper chart) with 3.0 being comparable to a paper chart was utilized. The mean of the individual question responses are found in Appendix 1. The mean of each response in this section very significantly exceeded the 4.0 evaluation point of "somewhat better than paper chart".

Question 4.10 was a Summary Evaluation inquiry requesting the operator to score the following:

> **"RCDS with adequate back-up arrangements used together with an appropriate folio of up-to-date paper charts…may be accepted as complying with the chart carriage requirement of SOLAS."**

Because of the statement's broad and far-reaching implications for mariners, the operator responses to this question are the most significant benchmark of the survey project. Figure 6 illustrates the distribution of the responses to the important all-inclusive # 4.10 question.

Overall, the 268 responses to Part 4 questions had a mean answer of 4.71. The aggregate distribution of all answers to Questions # 4.1 to 4.10 is portrayed in Figure 7. These 96% approval ratings (4 + 5) of the overall responses indicate an overwhelming operator approval of RCDS as a navigation tool.

FIGURE 6: QUEST. # 4.10 RESPONSES

RCDS with adequate back-up arrangements used together with an appropriate folio of up-to-date paper charts…may be accepted as complying with the chart carriage requirement of SOLAS."

DISTRIBUTION OF

QUESTION # 4.10 ANSWERS

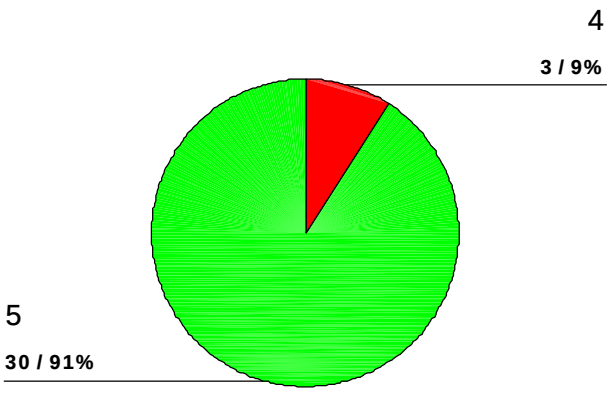
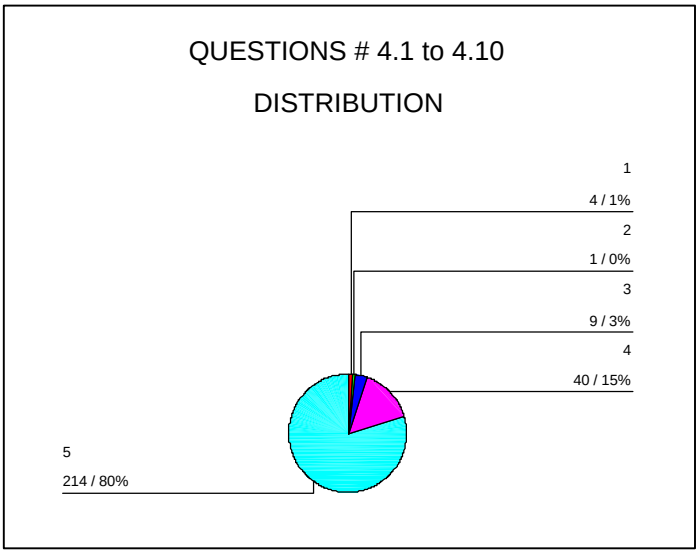
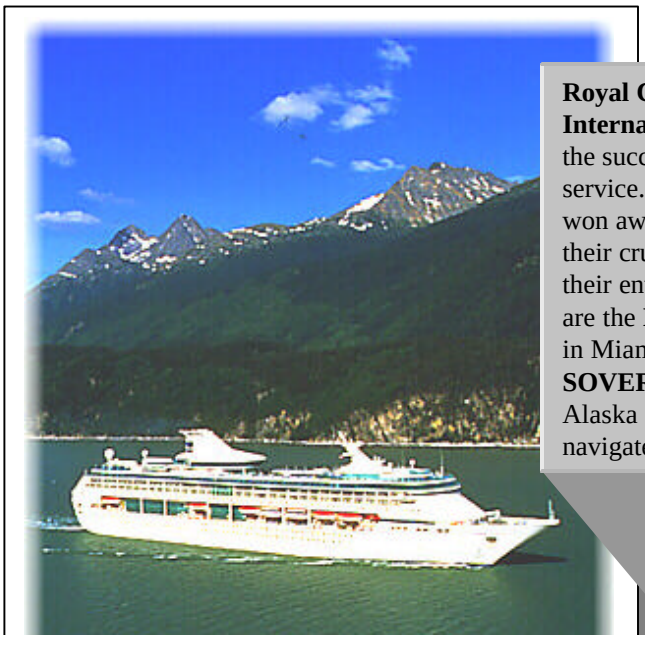
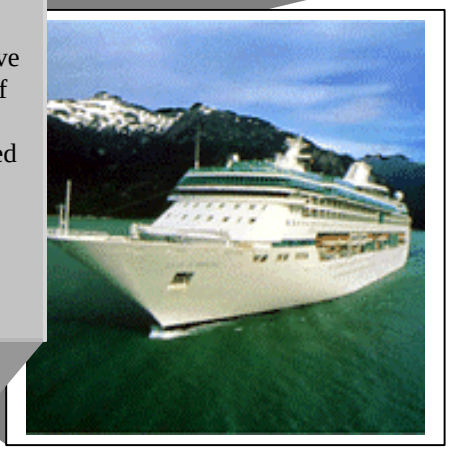


FIGURE 7: "OTHER" RESPONSES
QUESTIONS # 4.1 to 4.10





Royal Caribbean Cruise Lines International takes great pride in the success of its award-winning service. Through the years they have won awards honoring the quality of their cruises, cruise members and their environmental efforts. Pictured are the **LEGEND OF THE SEAS** in Miami (upper rt.) and **SOVEREIGN OF THE SEAS** in Alaska (rt. and lt.) while being navigated with the aid of NOAA'



RCDS FIELD TEST ABOARD M/V NEOMA

The author conducted a field test voyage of the NOAA raster charts as part of the survey project. The exercise involved evaluation of the NOAA raster chart No. 11326, 11328 and 11329 for the upper Houston Ship Channel (HSC) while the M/V NOEMA was operating as a light boat in the 250 feet wide upper channel. The vessel performed a variety of boat handling maneuvers typical to its daily operations (i.e. backing and filling, course changes, meeting/overtaking situations, barge fleet maneuvering, etc.) The witnessing was performed to:

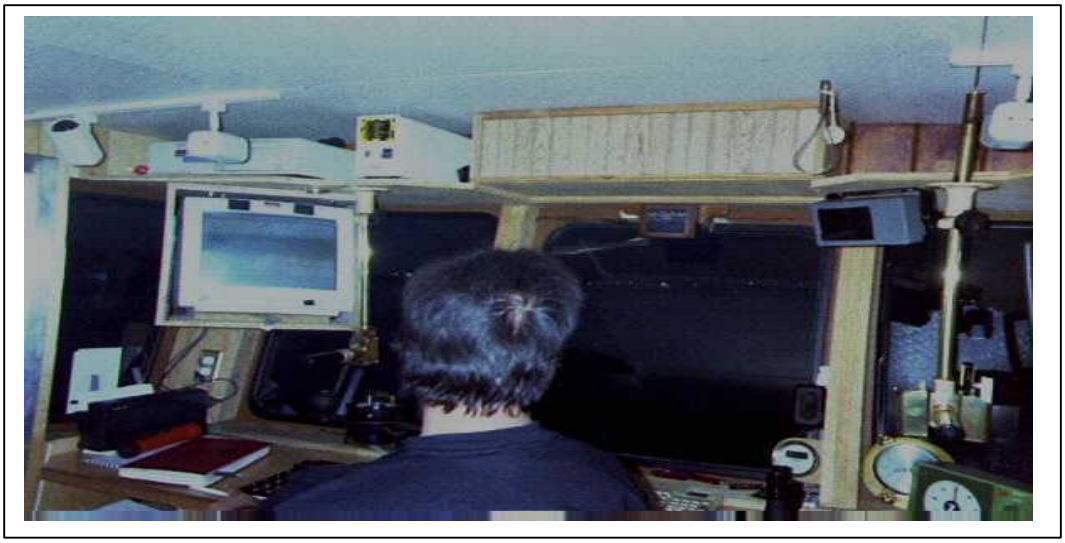
- facilitate the Survey Questionnaire
- Determine the correct interpretation of the Survey Questions were being made
- Gather first-hand observations to assist in results interpretation

During this five hour phase (half daylight and half night-time), the RCDS performed in a most professional and acceptable manner. The DGPS display was highly accurate and totally reliable with the sole exception of a twenty second signal loss when the vessel passed under the I-10 bridge. Captain LeBlanc attentively referred to the RCDS display for bathymety information while in the Brady Island and Carpenter Bayou barge fleets. He also utilized the RCDS to identify locations where two other towboat units were reporting from . He subsequently assessed on the RCDS where his vessel would meet the others and noted the charted information for these locales. As Captain LeBlanc was familiar with the HSC, he primarily relied on the RCDS for voyage monitoring and this author would rank his usage as low to moderate. In two maneuvering situations, Captain LeBlanc pointedly remarked that he was “glad that he did not have to fumble around for a flashlight and chart and could focus his attention on the situation outside the wheelhouse window !”.

The author’s observation of the RCDS depiction of the vessel’s location, as portrayed on the screen, was within 20 – 30 feet of reality in a direction lateral to the vessel’s trackline and within fifty feet along the vessel'' direction of travel. It was noted that during the periods when the vessel slowed down, the RCDS positional display appeared to improve to an even greater accuracy. The charted features on the screen appeared to be of a high accuracy and were consistent with the author’s nautical chart experience.

Illustration 4:

Hollywood Marine, Inc. **M/V NOEMA** at Port Lavaca, TX. Dock with Captain Ricky Leblanc and Pilot Ken Penn.



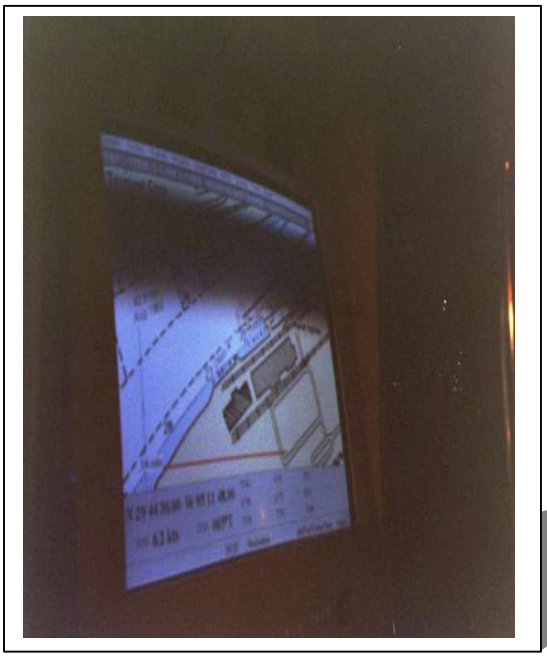
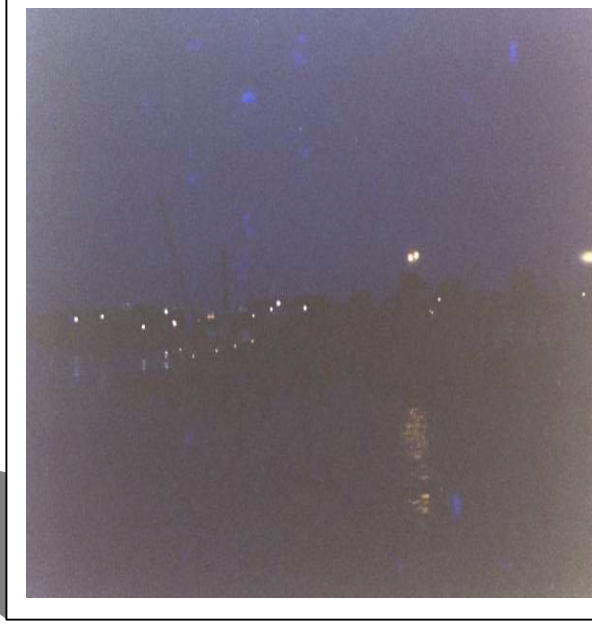


Illustration 5: Capt. LeBlanc, **M/V NOEMA** (above) in night-time (rt.) meeting situation with an ocean vessel on the Houston Ship Channel & RCDS night –time displays (lt.& btm.) of Raster Charts



After the initial harbor assessment of the Raster Chart performance was completed, the M/V NOEMA picked up her 260 ft. petroleum barge at the Hollywood facility. The vessel and barge were now a unit almost 350 ft. long. The towboat and barge proceeded down the HSC and across Galveston Bay. After checking the current conditions of Bolivar Roads on the NOAA PORTS system, the flotilla entered into the Gulf Intra-coastal Waterway and proceeded westbound towards Port Lavaca, TX.

At the head of Galveston Bay, it was necessary for the M/V NOEMA to pull out of the channel to adjust her towing wires prior to crossing the open waterway. Captain LeBlanc used the RCDS display to select an appropriate site to approach the bank where the barge nosed into the sand in a locale where the deeper draft (9ft. 06 in.) towboat remained afloat at all times.

While crossing Galveston Bay, Pilot Ken Penn remarked and demonstrated how the RCDS was such a positioning asset for towboats while they crossed the large bays and sounds common to the Gulf Coast. This correlates with the navigator's difficulty in visually assessing his position when quite distant from the shore.

Enroute to Port Lavaca, the M/V NOEMA stopped at Chocolate Bayou to swap-out her barge for another one of the type suitable for the product to be loaded in Port Lavaca. Both inbound and outbound to Chocolate Bayou, the Captain and Pilot expressed concern about the confusing buoyage of this locale and remarked about the ease with which the RCDS system enabled them to mentally link radar targets and charted buoys.

After Chocolate Bayou, the vessel and tow passed through two sets of Army Corps of Engineers locks (Reference cover sheet picture.). Again the operators lauded the benefits of RCDS. This time it was with respect to RCDS assistance in lining up for the locks and monitoring vessel set in the treacherous currents of the Colorado River area.

During the thirty-two hour transit from Houston to Port Lavaca, the vessel and tow transited through areas of high and low density traffic. The time was approximately half night and half daylight. The visibility ranged from moderate to good. The route transited was a very environmentally sensitive and remote region of the Texas Coast and it abutted the very sensitive Aransas Wildlife Refuge which is the winter home of the endangered whooping crane. Captain LeBlanc commented as to the professional comfort level and improved navigational safety that RCDS provided while transiting this environment with 10,000 barrels of petroleum products. He stressed how forward-thinking his company, Hollywood Marine Inc. was in providing RCDS as a lot of towing companies did not have this navigational aid.

Twice during the voyage, Captain LeBlanc was observed to heavily rely upon the RCDS, at night, to adroitly and professionally steer his vessel and tow between the close-aboard starboard hand bank and oncoming 1300 ft. tow flotillas which were certainly "crowding" the NOEMA and her barge.

The author remained on the bridge of the NOEMA practically the entire transit to Port Lavaca. During this period of RCDS observation, the author was very impressed by the positioning accuracy portrayed by the RCDS display and the locational accuracy of the charted objects. Not once, during the transit, did the DGPS indicator on the RCDS depart the charted limits of the ICW. At all times, the positioning of the vessel on the raster chart was within fifty feet of this experienced mariner's "seaman's eye". The only cautionary comment received about RCDS from the Captain and Pilot was that they were not yet ready to proceed in zero visibility on the basis of RCDS and radar alone. This is regarded as prudent seamanship in the eyes of the author.

CONCLUSIONS:

The statistical results of the survey indicate a very strong mariner approval of the NOAA raster charts and the RCDS. During the analysis, a combination of the "4" + "5" percentages of answers was assessed an indication of an "approval rating" and conversely, the combination of answer "1" + "2" percentages would connote a disapproval rating of the raster chart/RCDS. The following table summarizes the survey results and confidence intervals (CI) by the four main survey categories.

OVERALL SURVEY RESULTS

Voyage Topic	Quest #	N #	Mn. Response	Low CI	High CI	% "4" Responses	% "5" Responses	Total "4+5" %age
Planning	1.1-1.33	939	4.50	4.45	4.55	17 %	69 %	86 %
Monitoring	2.1-2.53	1362	4.63	4.57	4.67	15 %	76 %	91 %
Recording	3.1-3.6	169	4.63	4.51	4.76	15 %	77 %	92 %
Other	4.1-4.10	268	4.71	4.63	4.80	15 %	80 %	95 %

The "tightness" and consistency of the results over the various voyage topics is interpreted as the respondent's maintaining their individual professional consistencies throughout the 102 questions per survey. This consistency also supports the "approval/disapproval" concept and the results of the operator's overall approval rating.

SUMMARY QUESTION RESULTS

Survey Quest #	Mn. Response	Low CI	High CI	% "4" Responses	% "5" Responses	Total "4+5" %age
1.32	4.68	4.55	4.81	16 %	77 %	93 %
1.33	4.92	4.85	4.99	0 %	96 %	96 %
2.50	4.90	4.85	4.95	10 %	90 %	100 %
2.51	4.70	4.59	4.81	15 %	76 %	91 %
2.52	4.31	4.25	4.37	24 %	55 %	79 %
2.53	4.82	4.72	4.92	4 %	89 %	93 %
3.4	4.63	4.50	4.76	20 %	73 %	93 %
4.10	4.90	4.85	4.95	9 %	91 %	100 %

The large percentage of "5" ratings for the strategic summary Questions # 1.32, 1.33, 2.50, 2.51, 2.52, 2.53, 3.4 and 4.10 is further indication of mariner approval of raster chart systems. Each of these summary Questions had mean responses significantly above the "4" rating of "somewhat better than a paper chart". The most significant finding of the survey was the 100% respondent approval rating for the all inclusive RCDS statement (# 4.10) regarding acceptance of raster charts/RCDS as chart carriage equivalent under SOLAS.

In light of the foregoing, a reasonable man must statistically conclude that the NOAA raster charts and the RCDS are enhancing the safety and efficiency of marine transportation in and around the United States. Yet, the following extracts from the respondents conveys this conclusion in an even more clear and concise manner.

- ***"RCDS with adequate back-up arrangements used together with an appropriate folio of up-to-date paper charts…may be accepted as complying with the chart carriage requirement of SOLAS."***
- ***"Great Improvement. Get update on charts. Safer. Don't have to look for other charts or use flashlights. Can look over to the chart on the computer instead of having to unfold it."***
- ***Don't like foldout charts. Really great trip because I had electronic chart. Most tugboat wheelhouses don't have a big enough chart desk for paper charts. Find RCDS a big time help with all the new people and planning and training new pilots.***
- ***Raster Chart Display Systems are an acceptably accurate aid to navigation, which makes vessel operation and the marine environment SAFER.***

The foregoing remarks of the participating RCDS operators capture the true maritime industry conclusions regarding the improvements in navigation safety and efficiency brought about by the NOAA raster chart. An author can validate the sentiments and technical details of this study with graphs and statistics. But, like the inadequacies of a paper chart document, this document will never be able to fully capture or convey the degree of the mariners' professional enthusiasm for RCDS which they shared with this fellow-mariner. Whatever the future international outcome may be, NOAA can be most proud of the contribution and improvement they are making to the maritime field and the safety of the American Waterways.

Acknowledgements:

No project is complete due to the efforts of one single person. The author acknowledges the contributions of the following Mariners for enabling the accomplishment of this document:

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- Captain John Hoopaugh, Hollywood Marine Inc.
- Captain David Julius, Hollywood Marine Inc.
- Captain R. LeBlanc, Master**, M/V NOEMA** and Pilot K. Penn

APPENDIX 1

RASTER CHART DISPLAY SYSTEM USER SURVEY

WITH

MEAN RESPONSES/ STANDARD ERROR / N-RESPONSES

RASTER CHART DISPLAY SYSTEM
FIELD TEST/USER SURVEY

IDENTIFICATION INFORMATION

Name of Vessel _____
Type, Tons, Length _____
Company Name _____
Contact Name _____
Address _____
_____
_____
Telephone _____
E-Mail _____

RASTER CHART EQUIPMENT IN USE DURING TEST

Navigation Software _____
Version _____
Manufacturer _____
Computer _____
Monitor Size _____
Monitor Resolution _____
Raster Data Brand _____

OTHER EQUIPMENT IN USE DURING TEST

Indicate (Y/N) as to whether the equipment is integrated with the raster chart navigation software. Then indicate the manufacturer and model.

GPS (Y/N) _____
DGPS (Y/N) _____
Radar (Y/N) _____
ARPA (Y/N) _____
LORAN C (Y/N) _____
Speed Log (Y/N) _____
Compass (Y/N) _____
Other (Y/N) _____

OPERATOR (repeat on back if other operator's experience is combined in test report.)
Operator's Name _____
Operator's Rank _____
RCDS Experience_____1.18 years/ 0.79 Std Dev / 27 # / 4.18 yr range___
Years Experience as

- ■ helmsman _ 21.0 years/ 10.4 Std Dev. / 17 # / xx yr range
- ■ navigation/chart work _19.6 years / 11.4 Std Dev. / 17 # / 42 yr range
- ■ officer of the watch __13.6 years / 10.36 Std Dev. / 7 # / 28 yr range
- ■ Captain/Master _14.9 years / 9.2 Std Dev. / 24 # / 36 yr range
- ■ pilot _ 6.9 years / 6.7 Std Dev. / 19 # / 22.5 yr range
- ■ other (specify) _ 7.7 years / 7.2 Std Dev. / 4# / 16.0 yr range

TEST AREA

Describe the main routes or general geographic area where the RCDS was being used and evaluated:
Panama City , Fl to Brownsville, TX // Up and Down Mississippi River // SW Pass to Baton Rouge, LA //
Corpus Christi, New Orleans, Florida, Mississippi Sounds // ICCW and Inland Waters // ICW, Ship Channels, Mississippi Rivers // Houston Ship Channel // Southern Caribbean , U. S. West Coast , Alaska //

NAVIGATION ENVIRONMENT

Estimate as a percentage of the total experience being reflected in this test report, the amount of time the RCDS was being used in the following situations.

Open Water Passage _15.2 % mean total 100%
Coastal Transit _____28.2 % mean
Harbor & Approach _22.3 % mean
Channels/Constricted ____45.7 % mean
Docking _____11.0 % mean
Other (specify) _____7.8 % mean
total =/= 100%

Excellent Visibility _38.4 % mean
Fair Visibility _25.2 % mean
Poor Visibility _21.5 % mean
No Visibility _19.1 % mean
total 100%

Heavy Traffic _ 34.2 % mean
Medium Traffic _ 36.1 % mean
Light or No Traffic _ 38.7 % mean
total 100%

Day Navigation _____50.4 %
Night Navigation _____49.6 %
total 100%

Quiet Seas _ 38.4 % mean
Light Seas _ 27.8 % mean
Moderate Seas _ 23.3 % mean
Heavy Seas _ 21.1 % mean

Approximate Total Days of Navigation
Being Summarized in This Test Report: 297.9 days mean // 56.2 Std Dev. // 12# // 180 d range // 3575 d total
Over How Long a Period? _ approximately 365 day period _
(example answer: Approx. 8 months over 1 year with the rest being in-port periods.)

EVALUATION SCALE (use for all questions)

DESCRIPTORS & SCORE					
does not apply	**much worse than paper chart**	**somewhat worse**	**comparable to paper chart**	**somewhat better**	**superior to paper chart**
0	**1**	**2**	**3**	**4**	**5**
cannot comment	**significant problem**	**minor problem**	**no problem**	**minor advantage**	**significant advantage**
0	**1**	**2**	**3**	**4**	**5**
did not observe	**hard to use**	**moderately difficult use**	**adequate ease of use**	**moderately easy to use**	**easy to use**
0	**1**	**2**	**3**	**4**	**5**
did not use	**inadequate**	**marginal**	**acceptable**	**good**	**excellent**
0	**1**	**2**	**3**	**4**	**5**

EVALUATION SCALE (use for all questions)

1. RCDS AS A VOYAGE PLANNING TOOL

If using an RCDS for voyage planning is about the same as using a paper chart, then score the item in the middle of the range at "3".

Ref #	Scores (1-5 or 0)	Questions (compared to paper chart performance where appropriate)
	/Std mean/ Err	**How would you evaluate doing the following navigation functions with a raster chart compared to doing the comparable functions on a paper chart?**
1.1	4.58 / .15	- entering routes, the adequacy of the number that could be entered?
1.2	4.70 / .15	- entering waypoints and if an adequate number were allowed?
1.3	4.70 / .08	- adding waypoints to a route after entering or reloading it?
1.4	4.41 / .14	- deleting waypoints from a route?
1.5	4.51 / .13	- changing the position of a waypoint?
1.6	4.30 / .14	- changing the order of waypoints in a route?
1.7	4.45 / .17	- entering an adequate number of alternative routes?
1.8	4.10 / .22	- distinguishing alternate routes from the principal one?
1.9	4.52 / .19	- displaying routes over other charts?
1.10	4.74 / .07	- reloading previously planned routes for further planning?
1.11	4.70 / .12	- dropping or inserting waypoints in real-time as you went?
1.12	4.68 / .15	- loading load tracks actually sailed for use in planning?
1.13	4.76 / .13	- specifying a cross-track error to trigger an automatic alarm?
1.14	3.86 /	- entering and annotating marks (operator-entered points)?

	.24	
1.15	4.56 / .12	- editing and/or deleting marks?
1.16	4.41 / .17	- entering points, lines or areas which would activate an alarm such as guard zones, boundaries, range circles, etc.?
1.17	4.03 / .23	- entering notes that you wanted to enter?
1.18	3.94 / .33	- preparing a printed a voyage plan, a get home chartlet, GPS waypoints?

	/Std mean/ Err	**Remember, you are to evaluate doing the following navigation functions using a raster chart compared to doing the comparable functions on a paper chart.**
1.19	4.72 / .08	- calculate the distance of your planned trip?
1.20	4.91 / .05	- calculate bearing and distance to waypoints?
1.21	4.75 / .07	- estimate transit time(s)?
1.22	4.76 / .09	- recalculate time along track if you moved waypoints?
1.23	4.84 / .06	- readily display all the charts you needed?
1.24	4.81 / .09	- move around the chart (pan and zoom) while planning?
1.25	4.24 / .22	- display previously entered data over any chart you wanted?
1.26	4.62 / .11	- make the planning assessments and judgements that you would make with a paper chart?
1.27	4.82 / .06	How was the planning workload compared to a paper chart?
		Score the following questions without comparing to a paper chart.
1.28	4.47 / .12	How was the legibility of the chart image during your planning session?
1.29	4.00 / .18	How was the impact on planning of seeing only a <u>portion</u> of a chart on the screen at one time?
1.30	3.67 / .21	How was the impact of chart notes not always being visible?
1.31	4.00 / .19	How was the impact of some charts being on different map projections?
1.32	4.68 / .13	How would you compare planning using a raster chart system with planning using manual means and a paper chart?
1.33	4.92 / .07	Were there any fundamental limitations to planning using raster charts that were not just a limit of your software? What were they?

2. RCDS FOR VOYAGE MONITORING

If using an RCDS for **voyage monitoring** is about the same as a paper chart, thun score the item in the middle of the range at "3".

Ref #	**Scores** (1-5 or 0)	**Questions** (compared to paper chart performance where appropriate)
	/Std Mean/Err	**How would you evaluate doing the following navigation functions using a raster chart compared to doing the comparable functions on a paper chart?**
2.1	4.56 / .09	- displaying clearly all chart and voyage monitoring information?
2.2	4.35 / .19	- add or remove mariner-added information?

2.3	3.55 / .26	- display, hide or query mariner-added information?
		Remember, you are to evaluate doing the following navigation functions using a raster chart compared to doing the comparable functions on a paper chart.
2.4	4.70 / .08	- determine if a larger scale chart covers the area you are navigating?
2.5	3.9 / .18	- distinguish the ship's track and mariner's notes on the image?
2.6	4.71 / .10	- showing your position accurately on the chart in real-time?
2.7	3.31 / .27	- performing dead reckoning if your positioning system failed?
2.8	4.80 / .07	- displaying a planned route?
2.9	4.29 / .17	- displaying an alternate route in addition to the selected one?
2.10	4.3 / .17	- distinguishing the alternative route from the selected one?
2.11	4.71 / .15	- modifying the selected route?
2.12	4.90 / .05	- find and display any chart easily during voyage monitoring?
2.13	4.85 / .06	- move around the chart (pan and zoom) to monitor your voyage?
2.14	4.81 / .09	- look-ahead on the route during route monitoring?
2.15	4.62 / .09	- achieve an adequate overview of the voyage and route?
2.16	3.36 / .24	- transfer information you entered other charts?
2.17	3.16 / .26	- view chart notes which were located off-screen?
2.18	4.46 / .16	- create event marks at any time and annotate them?
2.19	4.66 / .11	- estimating of arrival time compared to a paper chart?
2.20	4.84 / .06	- display the coordinates of any point on demand?
2.21	4.77 / .10	- enter coordinates and then display that position on demand?
2.22	4.93 / .05	- determine your lat./long. at any time?
2.23	4.78 / .09	- dynamically measure range and bearing to charted objects?
2.24	4.94 / .03	- monitor voyage parameters (speed over ground, course over ground, speed made good, time to go,...)?
2.25	4.67 / .15	- switch from chart to chart manually in a convenient manner?
		Score the following questions without comparing to a paper chart.
2.26	4.72 / .12	The adequacy of the screen size?
2.27	4.50 / .12	Screen "clutter" compared to a paper chart during voyage monitoring?
2.28	4.28 /	The night colors for comfortable and legible viewing?

	.17	
2.29	4.90 / .07	Did the ship and route automatically appear whenever the display covered that area?
2.30	4.90 / .07	Did the chart automatically pan as the ship reached an appropriate distance from the edge of the screen?
2.31	4.80 / .07	View an area of the chart that did not contain the ship and have route monitoring/positioning continue in the background?
2.32	4.25 / .19	By a single action, show chart scale, datum, and depth and height units?
2.33	4.61 / .14	Determine range and bearing to items that were off-screen?
2.34	4.87 / .05	Restore the ship-centered display with a single action?
2.35	4.89 / .07	Did waypoint arrival alarms work as you wished?
2.36	4.89 / .04	Did boundary crossing alarms work as you wished?
2.37	4.34 / .12	Were there frequent false alarms?
2.38	4.84 / .09	Did an alarm sound when you exceeded the cross track error limit?
		Remember, you are scoring the following questions without comparison to a paper chart.
2.39	4.73 / .08	Did an alarm sound if the ship, within a mariner-specified time or distance, was to reach a critical point on the planned route?
2.40	4.37 / .26	Did your system give an indication if positioning system input was lost?
2.41	4.46 / .26	If 2 positioning systems were used simultaneously, did the system identify discrepancies between the two?
2.42	4.50 / .15	Was route monitoring carried out in a simple and reliable manner?
2.43	4.84 / .06	In restricted waterways, how was the RCDS as a voyage monitoring tool compared to the paper chart?
2.44	4.81 / .08	In congested waterway situations, how was the RCDS as a voyage monitoring tool compared to the paper chart?
2.45	4.62 / .14	Could time-labels along the ships track be displayed easily at a range of intervals between 1 and 120 minutes?
2.46	4.83 / .14	Were you always able to navigate north up?
2.47	5.0 / .00	If course-up navigation was offered, how was it compared to using a paper chart?
2.48	4.90 / .08	How would you compare voyage monitoring using a raster chart system with voyage monitoring using a paper chart?
2.49	4.84 / .08	How was the voyage monitoring workload compared to a paper chart?
2.50	4.90 / .05	How would you rate using RCDS as the primary means of navigation compared to paper charts?
2.51	4.70 / .11	How would you evaluate the impact on the safety of navigation when using an RCDS as opposed to a paper chart?
2.52	4.31 / .16	Are there circumstances where you would not use RCDS for voyage monitoring? When?

2.53	4.82 / .10	Were there any fundamental limitations to voyage monitoring with raster charts that were not just a limit of your software? What were they?

3. RCDS FOR VOYAGE RECORDING

Ref #	Scores (1-5 or 0)	Questions (compared to paper chart performance where appropriate)
3.1	4.84 / .10	Could you record sufficient information to determine the ship's **past** track, time, position, heading and speed?
3.2	4.63 / .17	Were you able to add log entries manually?
3.3	4.16 / .40	Could you automatically record the official data used (RNC, edition, date and update history)?
3.4	4.63 / .13	Were you able to gather an adequate record of the voyage compared to using a paper chart?
3.5	4.44 / .14	Could you record the entire course made good with time marks at intervals not exceeding 4 hours?
3.6	4.80 / .08	Were you able to save at least the previous 12 hours of voyage track?

4. **OTHER**

Ref #	Scores (1-5 or 0)	Questions (compared to paper chart performance where appropriate)
4.1	4.83 / .06	Were the accuracy of all calculations independent of the characteristics of the display and consistent with the RNC accuracy?
4.2	4.87 / .07	Were bearings and distances measured on the display as accurate as that afforded by the resolution of the display?
4.3	4.64 / .24	Could you make manual updates to the chart that were distinguishable from the original chart without affecting the legibility of the chart?
4.4	4.54 / .16	Did the RCDS degrade the performance of any equipment that was connected to it?
4.5	4.51 / .12	Once learned, how user-friendly would you judge the RCDS to be?
4.6	4.66 / .19	Did connection to other equipment degrade RCDS performance?
4.7	4.22 / .25	Did your system give adequate indication of system malfunction?
4.8	4.80 / .07	Were you able to execute in a convenient and timely manner all route planning, route monitoring and positioning performed on a paper chart?
4.9	4.93 / .04	How much would you say the RCDS reduced the navigational workload compared to using a paper chart?
4.10	4.90 / .05	**Summary Evaluation**: Considering all of your experience and the questions asked above, how would you score the following statement? "RCDS with adequate back-up arrangements used together with an appropriate folio of up-to-date paper charts ... may be accepted as complying with the chart carriage requirements of SOLAS."

Make any other comments you feel are relevant to the use of RCDS as the primary means of navigation on the back of this page.

APPENDIX 2

RASTER CHART DISPLAY SYSTEM USER SURVEY

GENERAL OPERATOR COMMENTS

Responses to Raster Chart User Survey Part 5: OTHER COMMENTS

- **"Great Improvement. Get update on charts. Safer, don't have to look for other charts or use flashlights. Can look over to the chart on the computer instead of having to unfold it."**
- **"Up-dated charts. Real-time activation. Larger area of visibility while maintaining integrity of the chart (i.e. readability)"**
- **"Need easy way to update chart programs. Would like to see Notice to Mariners too (to update buoys & lights, warnings)"**
- **"Why would anyone want to spend time finding where you're at on a shit paper chart, when with the RCDS all you have to do is look over to your computer screen . Do away with all paper charts, and always keep our charts updated on the RCDS."**
- **"I think the system is great. It can only get better. Used a lot onboard."**
- **"I know the software and tapes are a lot better than the maps they used to have. The software needs to be mandatory. That is how important it is."**
- **"Put mile markers every mile on RCDS charts. Add dock names. Make up electronic charts for areas where towboats go and no charts available (i.e. Black Warrior River; Tombiggee; Red River; Escambia River; Birmingham to Tuscaloka)"**
- **"This is a great aid. Hopefully this will continue to be our system."**
- **"RCDS has brought the towing industry into the future with a valuable piece of equipment for safer navigation, earlier detection to prevent grounding, collision. Would like to see weather displays and predictions to help plan our voyage. When crossing the Mississippi Sound 24 to 48 hour prediction would be great."**
- **"Greatest thing there is."**
- **"Whenever I feel a chart is needed, I believe it would be much safer to use the monitor other than fumbling with paper charts & trying to navigate."**
- **" Working in the harbor, I have not had much of an opportunity to use the RCDS for navigation assistance. However, I would much rather use the system over paper charts when needed."**

ADDITIONAL COMMENTS RECORDED BY INTERVIEWER:

- "Don't like foldout charts. Really great trip because I had electronic chart. Most tugboat wheelhouses don't have a big enough chartdesk for paper charts. Find RCDS bigtime help with all the new people and planning and training new pilots"
- "Safety Benefits. Charted names is a big plus, knows better the area around you because a lot of young pilots out there running by charts and not using the old terminology. Been reliable."
- "Likes to go up to 24 mile scale and see planning overview enroute. Cross-track error very good on the Sounds."
- "Hell of a lot better than a paper chart."
- "Southbound, while trying to figure out 3 or 4 bends ahead of where at, the RCDS helps a lot with picturing where he will meet them. Likes zoom lock and zooms it out."
- "A lot easier than chasing down that stupid paper chart."
- "USCG asks for positions in Lat/Long, not mileboards."
- "Would like to have an offset center to see more ahead and less behind."
- "Cuts down on chances of accidents & groundings."
- "Don't have to dig for chart, flashlight. Risk goes way up if you have to do this while entering a potential accident."
- "Reduces risk of accident during 2 - 3 minutes of searchlight blindness."
- "Get it so it picks up oncoming traffic would help a lot."
- "A lot of boats don't have updated charts aboard or even any charts, so those required to have RCDS units are way ahead of before."
- "A worthwhile tool to have."
- "Can start playing a major role in reducing accidents."
- "Can concentrate more on what you are doing."
- "It can be an early warning system of where banks form."
- This would have prevented the RR bridge accident. The radar doesn't tell you what "foul ground" you are looking at."
- "Modernizing the towboat industry."
- "At a touch of a finger, you've got it versus digging around, then you get out of line. These canals are not wide."
- "It aids us to do our work a great deal."
- "You need more of your attention out on the head of the tow and not buried in a paper chart or, worse, looking for the paper chart."
- "It's a valuable and necessary tool."
- " Something like this could have prevented the two crewboats that hit the jetty at Galveston."
- "Radar helps, but this helps much more because of the detail."
- "Helps boats coming in from offshore."
- "Helps safely land tow on bank in fog."
- "This {RCDS} is a stress reducer."